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Hermaphroditic sexual system, entomophily and polychory in *Cleome monophylla* L. (Capparaceae), an annual erect herbaceous weed in farmlands of leguminous crops

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ABSTRACT

Cleome monophylla is a prominent colony forming weed in farmlands of leguminous crops. It is a hermaphroditic species and produces short, medium and long gynoecium floral types. Short and medium gynoecium floral types with strikingly separated stamens from the stigma promote cross-pollination while the long gynoecium floral type with closely spaced male and female sex organs promote self-pollination. However, short and medium gynoecium floral types have the possibility for autonomous pollination while long gynoecium floral type lacks this possibility. Early morning anthesis and attractive nectariferous flowers with exposed sex organs are adaptations for entomophily. Fruit is a many-seeded spindle-shaped capsular pod. Partial autochory, partial anemochory and partial hydrochory are functional. Seeds are flexible in germination ability depending on soil moisture and nutrient status. Therefore, the flexible hermaphroditic sexual system for the occurrence of cross- and self- pollination, entomophily, polychory and flexible seed germination ability enable *C. monophylla* to grow as a successful weed in leguminous crop fields.

Key words: *Cleome monophylla*, hermaphroditism, floral types, entomophily, polychory.

1. INTRODUCTION

In Capparaceae family, *Cleome* is the largest genus with about 200 species distributed widely in pantropical and sub-tropical regions of the world. Approximately 15 *Cleome* species have been reported in India (Raghavan 1993; Aparadh et al. 2012). In this genus, many species are protandrous, self-compatible and predominantly out-crossing (Iltis 1967). *C. spinosa* is polygamodioecious with pistillate, hermaphroditic and staminate floral types,

and pollinated by bats; sphingids, bees and hummingbirds act as nectar thieves (Machado et al. 2006). *C. lutea* and *C. serrulata* produce staminate and hermaphrodite flowers which attract bees, wasps and butterflies during daylight hours (Cane 2008). *C. gynandra* is polygamodioecious with functionally staminate short gynoecium, hermaphrodite medium and long gynoecium floral types, and is pollinated by insects and wind. *C. viscosa* is functionally hermaphroditic with short, medium and long gynoecium floral types, and is pollinated by insects (Solomon Raju and Sandhya Rani 2016). *C. monophylla* is distributed in tropical and subtropical Africa including Madagascar, India, Srilanka and Indian Ocean islands where it is widespread and not in danger of genetic erosion. It is used used as a vegetable in Africa, as a source of vegetable oil in Tanzania and to treat ulcers, boils and wounds in humans in India (Grubben 2004). In this paper, the floral features, floral types, pollination, seed dispersal and seed germination of *C. monophylla* are described in the light of lacuna of information on these aspects.

2. MATERIALS AND METHODS

Cleome monophylla L. (Capparaceae) growing wild in farmlands of leguminous crops near Modavalasa located in Denkada tehsil of Vizianagaram District, Andhra Pradesh, India was selected for study during the COVID-19 Lockdown/unlock period from June to August 2020. Twenty five fresh flowers were used to record the floral morphological details. Anthesis and anther dehiscence timings were noted by observing twenty tagged mature buds in the agricultural field. The flowers were classified based on the stigma and stamen size into different floral types. Floral characteristics were examined in detail to evaluate the possible pollination syndrome. Casual observations on nectar production and flower visitors were made during day-time from morning to evening. Fruit growth, development, maturation, seed dispersal and seed germination aspects were also noted briefly.

3. OBSERVATIONS

It is an erect annual herbaceous weed that grows throughout wet season from June-November. Seeds germinate in late May to early June and seedlings grow quickly (Figure 1a-c). Flowering begins in late June or early July and continues until late October or early November. The stem is either solitary or branched, angled cylindrical and densely covered with short glandular and long non-glandular velvety hair. Leaves are alternate, petiolate and simple with ovate-oblong blade, flat base, pointed tip and ciliate margins. The flowers are solitary in leaf axils but branch-ends present few-flowered racemes. They are open during early morning hours (Figure 1d). They are pedicellate, small, 5-7 mm long, light purple, asymmetrical, bisexual and nectariferous. The calyx has 4 free narrowly lanceolate 3 mm long sepals. The corolla has 4 light purple petals; individual petals are upright, 5-7 mm long, 2-2.5 wide and spathulate with clawed base and rounded tip. The stamens are usually 6 but rarely 5 with filaments of unequal size. The ovary is elongate, linear, 5-7 mm long, 1-celled and finely pubescent with short style and capitate stigma.

Figure 1. *Cleome monophylla*: a. Habitat, b. Close-up view of population, c. Individual plants, d. Flowers and buds.

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The flowers were classified based on the length of the gynoecium into four floral types, Short Gynoecium Flowers - 1 & 2 (SGF-1, SGF-2) (Figure 2a,b), Medium Gynoecium Flowers (MGF) (Figure 2c) and Long Gynoecium Flowers (LGF) (Figure 2d). In SGF, the gynoecium is in two different lengths and accordingly there are named as 1 and 2 types; the stamens according to the length of filaments present three different heights, two are the longest, two the smallest and two others at the position between the longest and smallest stamens. In MGF and LGF also, the stamens occur in three tiers but in the former type, each tier is with a pair of stamens but the distance between each tier of stamens is narrowed down while in the latter type, the longest tier of stamens is quite distinct from the other two tiers in which the distance between them is very narrow. Further, in LGF, the stigma is placed at the height of the lowest tier of stamens; such a placement enable the stigma to establish contact with the lowest tier of stamens with great ease and it is further empowered by wind as the stamens are freely exposed far above the divergent petals. The floral characters are similar for all four floral types which are produced in the inflorescences of the same plant. Buds mature within two weeks after the initiation of bud formation. The flowers open at dawn during 0500-0600 h by the gradual separation and widening of petals exposing the vertically positioned stamens and the stigma but the petals stand nearly erect. The production of four floral types indicate that the plant has features for cross-pollination in preference to self-pollination. In SGF and MGF, the stamens coil and petals close back on the 2nd and 3rd day of anthesis facilitating the occurrence of autonomous pollination while in LGF, the stigma stands out while the stamens coil and petals close back indicating that there is no possibility for autonomous pollination. It is to be mentioned that the flowers attract the larva an unknown butterfly species and it feeds on the flowers (Figure 2e).

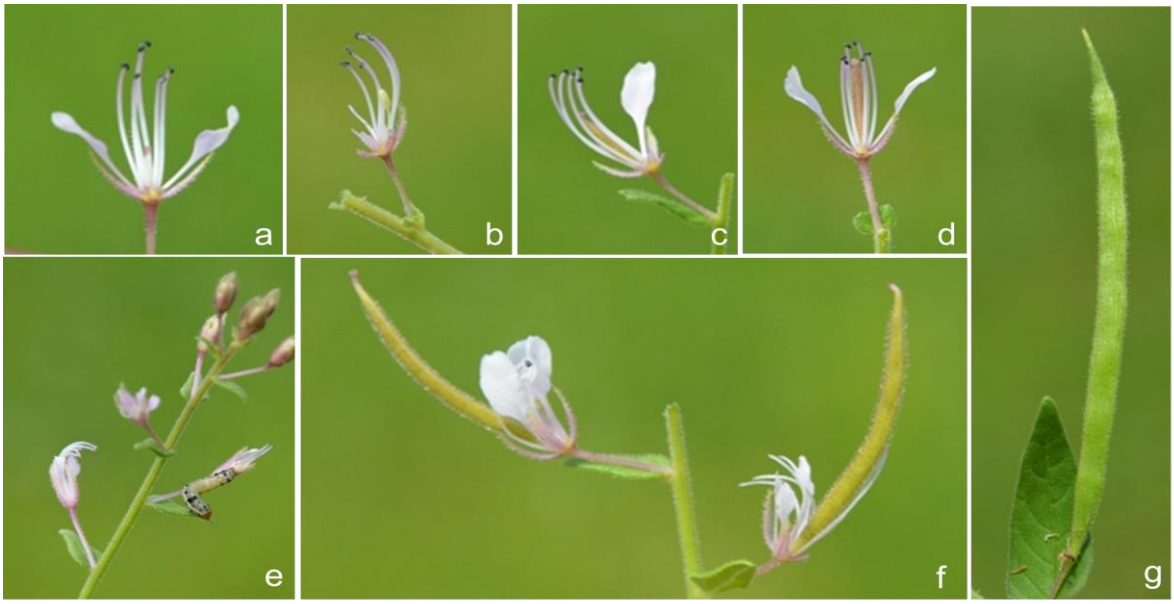

Figure 2. *Cleome monophylla*: a. Short gynoecium – 1 flower (SG1F), b. Short gynoecium - 2 flower (SG2F), c. Medium gynoecium flower (MGF), d. Long gynoecium flower (LGF), e. Butterfly larva feeding on floral parts, f. Fruit development while the floral parts are still intact, g. Fruit near maturation.

Fruit set is in open-pollinations is very high. Fruits mature within 2 weeks (Figure 2g). The sepals, petals and stamens remain attached to the fertilized flowers in vigorous form throughout fruit development and maturation (Figure 2f). Fruit is a stalked spindle-shaped 10-40 seeded 2-valved erect capsule, 7-10 cm long, subcylindric, beaked and densely covered with glandular and non-glandular hairs. The seeds are small, 2 mm wide, orbicular, and dark brown with fine longitudinal striations and low transverse ridges. The mature and dry fruit capsules split laterally and strongly wrinkle exposing the seeds some of which roll up on their own and fall off to the ground while other seeds are dispersed by wind especially on sunny days. The plant dries up and dies soon after fruit dehiscence and seed dispersal. The seeds germinate immediately and produce new plants if the soil is still wet or damp during the entire period of wet season.

4. DISCUSSION

Cleome monophylla grows like a crop in the wild in farmlands of leguminous crops but it is not found in rice fields where water-logged conditions exist. Since this plant grows as a crop and with profuse flowering at population level, the flowers with light purple corolla produced at the terminal portions of the plant are quite attractive and appealing. In Capparaceae family, *Capparis*

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herbacea, Cleome lutea, C. serrulata are andromonoecious, *Cleome rosea* trimonoecious, *Cleome spinosa* polygamodiecious (Inocencio et al. 2006; Carvalho 2002; Machado et al. 2006; Cane 2008), *Cleome gynandra* polygamodioecous producing andromonoecious and hermaphrodite individuals and *Cleome viscosa* hermaphroditic (Solomon Raju and Sandhya Rani 2016). In this study, *C. monophylla* is found to be a hermaphroditic species producing short, medium and long gynoecium floral types. The placement of stamens far above the stigma in SGF type and also in MGF type appears to be a mechanism to reduce the occurrence of self-pollination within and even between flowers of the same plant and hence these two floral types with strikingly separated stamens from the stigma are destined for the promotion of cross-pollination. In LGF type, the placement of lowest tier of stamens at the level of stigma and the other tiers of stamens slightly above the stigma facilitate and promote self-pollination within the plant. However, in SGF and MGF floral types, the coiling of stamens and vertical closure of petals on 2nd and 3rd day facilitate the occurrence of self-pollination. Therefore, the *C. monophylla* with hermaphroditic sexual system functional through different floral types is able to achieve cross- as well as self-pollination. But, this study suggests detailed field studies on different populations of this species to record the percentage of production of each floral type and pollen fertility rate of each floral type during initial, peak and final phase of flowering in order to evaluate the fruit set rate in open-pollinations. Similar hermaphroditic sexual system with floral types evidenced in *C. monophylla* has been reported in *C. viscosa* by Solomon Raju and Sandhya Rani (2016).

In *Cleome* species, different insects and other animals have been reported as pollinators. Bats are the pollinators for *C. spinosa* (Machado et al. 2006), bees, wasps and butterflies for *C. lutea, C. serrulata* (Cane 2008), bees, spiders and wind for *C. gynandra* (Chweya and Mnzava 1997; Solomon Raju and Sandhya Rani 2016), bees and butterflies for *C. viscosa* (Solomon Raju and Sandhya Rani 2016). In this study, flower foragers of *C. monophylla* were not observed but the flowers with exposed sex organs and non-tubular corolla with minute volume of nectar appear to be adapted for daytime foragers such as pollen and nectar collecting bees and nectar collecting butterflies. Since the plant shows anthesis during morning hours and present nectar and pollen since then continually for three successive days by the same flowers, it can be stated that this plant is adapted for entomophily.

Kokwaro (1976) reported that in *C. gynandra*, the capsules dehisce to release seeds which are spread by birds. Solomon Raju and Sandhya Rani (2016) reported that *C. gynandra* and *C. viscosa* dehisce their pods explosively and seeds are then dispersed by wind. In this study, *C. monophylla* produces many-seeded spindle-shaped capsular pods while the calyx, corolla and stamens are still intact and attractive. The pods split laterally and wrinkle to expose seeds some of which roll up on their own and find their into the ground while other seeds are driven away by wind due to their light weight. Further, fallen seeds in the soil have the possibility for dispersal by rain water. Therefore, *C. monophylla* is partly autochorous, partly anemochorous and partly hydrochorous, the first mode enables to build up populations at parental sites while the other modes enable seeds to migrate and form colonies in news areas.

Cleome species propagate mainly by seed (Ekpong 2009). In these species, seed germination is poor and delayed due to dormancy (Chweya and Mnzava 1997). *C. gynandra* seeds germinate immediately to produce new plants if the soil is damp. But, *C. viscosa* seeds are dormant and germinate only during rainy season (Solomon Raju and Sandhya Rani 2016). In *C. monophylla*, the seeds germinate immediately to produce new plants in damp sites but delay germination in dry sites until the wet seasons sets in. Therefore, this plant with different seed dispersal modes and flexible seed germination/dormancy is able to grow as a successful weed in leguminous crop fields.

5. CONCLUSIONS

Cleome monophylla grows as a wild crop in farmlands of leguminous crops. It is a hermaphroditic species and produces short, medium and long gynoecium floral types. Short and medium gynoecium floral types with strikingly separated stamens from the stigma promote cross-pollination while the long gynoecium floral type with closely spaced male and female sex organs promote self-pollination. However, short and medium gynoecium floral types have the possibility for autonomous pollination on 2nd and 3rd day of flower life while long gynoecium floral type lacks this possibility. The occurrence of anthesis during early morning hours and attractive nectariferous flowers with exposed sex organs are adaptations for entomophily. Fruit is a many-seeded spindle-shaped capsular pod. Mature pods split and wrinkle to expose seeds which settle on their own at parental sites or move away to settle at new sites through wind and water. Flexibility in seed germination ability enables the plant to produce new plants immediately after seed dispersal in damp sites and display dormancy if the site is dry. Therefore, the flexible hermaphroditic sexual system for the occurrence of cross- and self- pollination, entomophily, polychory and flexible seed germination ability enable *C. monophylla* to grow as a successful weed in leguminous crop fields.

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Authors contributions

All authors contributed equally.

Conflict of Interest

The authors declare that there are no conflicts of interests.

Ethical approval

The ethical guidelines for plants & plant materials are followed in the study for species collection & identification.

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Data and materials availability

All data associated with this study are present in the paper.

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